ELECTRICITY PRODUCTION BY MICROTURBINE

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ABSTRACT

The survey is based on the examination of the possible use of water power by building microturbines for electricity generation purposes. Water is one of the renewable sources, which can it be potential (water drop and flow) for convertion in "green energy".

POVZETEK

Raziskava temelji na proučitvi možne izrabe vodne energije z gradnjo mikroturbine za namene pridobivanja električne energije. Voda spada med obnovljiv vir, saj je njen potencial (vodni padec in pretok) možno pretvoriti v "zeleno energijo".

1. INTRODUCTION

Power supply is a basic necessity of modern human. In Slovenia we have at disposal two important renewable sources (wood and water). Water potential of rivers and streams would be reasonable better use by building modern micro power plants and thereby positively affect the overall power supply.

Micro systems operate on the principle of partial withdrawal of the amount of water from rivers or streams through pipes to microturbines. The latter pushes a generator and produces useful electricity. Exit water returns back to riverbed. System allows the main water flow unobstructed flow and thereby provides an acceptable intervention from an ecological perspective.

Micro systems (up to 50 kW) are suitable for rural and urban isolated places, where an investment in electrical network would be cost unfavourable. In this way cheap, continuous and environmentally acceptable power supply is provided. Electric current can be sent in the electrical network, stored in batteries or used directly [1, 2 and 3].

2. THEORETICAL BASES

Hydropower occurs in three forms. These are: kinetic (velocity), compressive and potential (positional) energy. Energy balance is represented by *Bernoulli* equation (1) [1, 3].

$$p + \frac{\rho \cdot v^2}{2} + \rho \cdot g \cdot H = k \tag{1}$$

where are: p - pressure, (N/m^2),
ρ - density, (kg/m^3),
v - water jet speed, (m/s),
g - gravity acceleration, (m/s^2),
H - water head, (m),
k - pressure constant, (N/m^2).

2.1 Calculation of the potential power of micro-hydro turbine

Layout and construction of micro-hydro power plant requires the calculation of the potential power of source utilization (2). On the basis of power, *P*, we decide on the possible construction of the power plant and the utilization of hydro power for useful purposes.

$$P = Q_V \cdot H \cdot g \cdot \rho \cdot (1 - \eta_{los}) \tag{2}$$

where are : P - power, (W),
Q_V - volume flow, (m^3/s),
H - water drop, (m),
g - gravity acceleration, (m/s^2),
ρ - water density, (kg/m^3),
η_{los} - pipeline energy losses, 1.

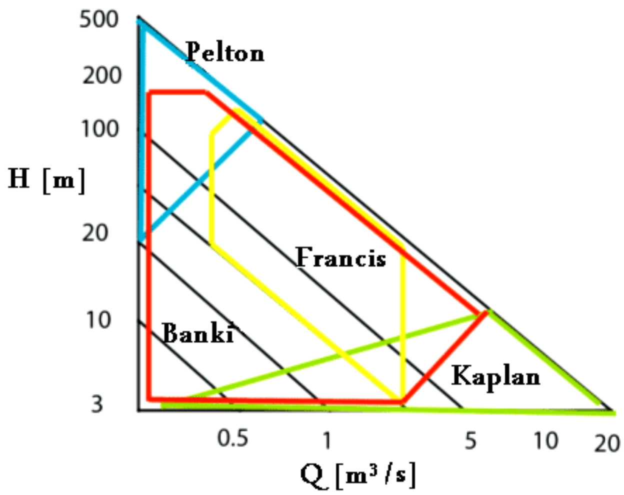
Maximal power of the water power utilization is the product of volume flow and possible height potential of the water source. With corresponding measurements we measure the water drop, *H*, and the average annual flow, Q_v, of the source.

2.2 Types of hydroturbines and appropriate choice

When choosing the type of hydroturbine two main groups are at our disposal: impulse and reaction turbines. Representatives of the impulse turbines are *Pelton* and *Turgo* turbine. Reaction turbines, based on lower water drops and big flows, are propeller turbines, and for medium flows and drops *Francis* turbine.

To facilitate the approach and decision making in choosing a suitable power plant it exists a phase diagram, in which the choice of turbine is a function of two variables (Img. 1)[1] [1, 2].

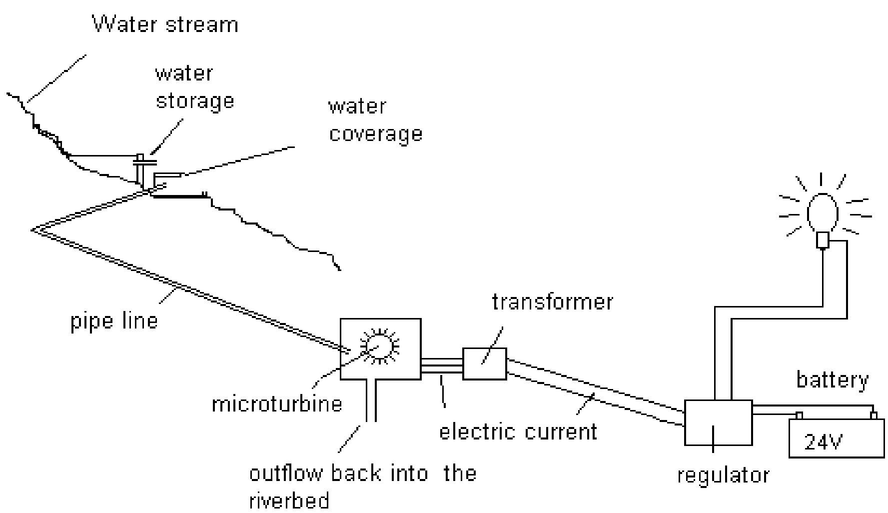
[1] http://www.energyalternatives.ca/shop/HydroCourse/images/111.gif



Img. 1. Choice of water turbine according to volume flow and water drop of the potential water source.

2.3 Power plant layout

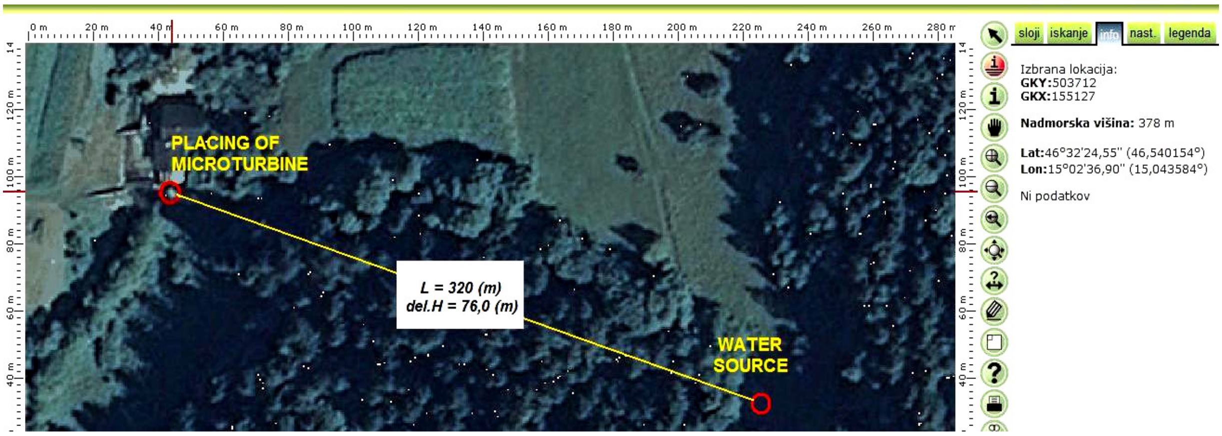
Regarding the power plant layout we can choose between several different constructions. Much impact on this has the chosen turbine type. Reaction turbines (propeller and Francis) are most frequently placed on the riverbed, near the riverbed or at the nearby withdrawal channel. At impulse turbines pipes are installed on the ground to the engine room, which may be close to a stream or a short distance away (Img. 2) [2, 3 and 4].



Img. 2. Schematic diagram of the utilization of water potential for electricity generation purposes.

3. PRACTICAL REALIZATION

I have come to the idea to build a micro-hydro power plant in my hometown (Koroška), where near the dwelling house from a steep slope runs a stream with an average annual flow of 3,2 (L/s). In the dry season water quality falls below 1,0 (L/s) and in winter the flow is approximately 4,0 (L/s). Maximum height difference between the coverage and the microturbine is 76,0 (m) (Img. 3).



Img. 3. Geographical map of water source location and of power plant layout.

3.1 Necessary calculations

For the actual planning and dimensioning input data of the studied system need to be measured (Table 1).

Table 1. Input data, required for calculations.

Physical quantity	*Value*
Volume flow range, $Q_{V1,3}$ (L/s)	**1 – 3**
Altitude 1, H_1 (m)	**459**
Altitude 2, H_2 (m)	**383**
Water density, ρ (kg/m^3)	**1000**
Gravitational constant, g (m/s^2)	**9,81**
Pipeline energy losses, η_{los}	**0,01**

A. CALCULETION OF THE WATER DROP

Water drop is equal to the difference between the altitudes of water coverage and of microturbine (3).

$$H = H_1 - H_2 = 459 - 383 = 76{,}0\,(\mathrm{m}) \tag{3}$$

B. CALCULETION OF THE POTENTIAL POWER OF THE WATER SOURCE

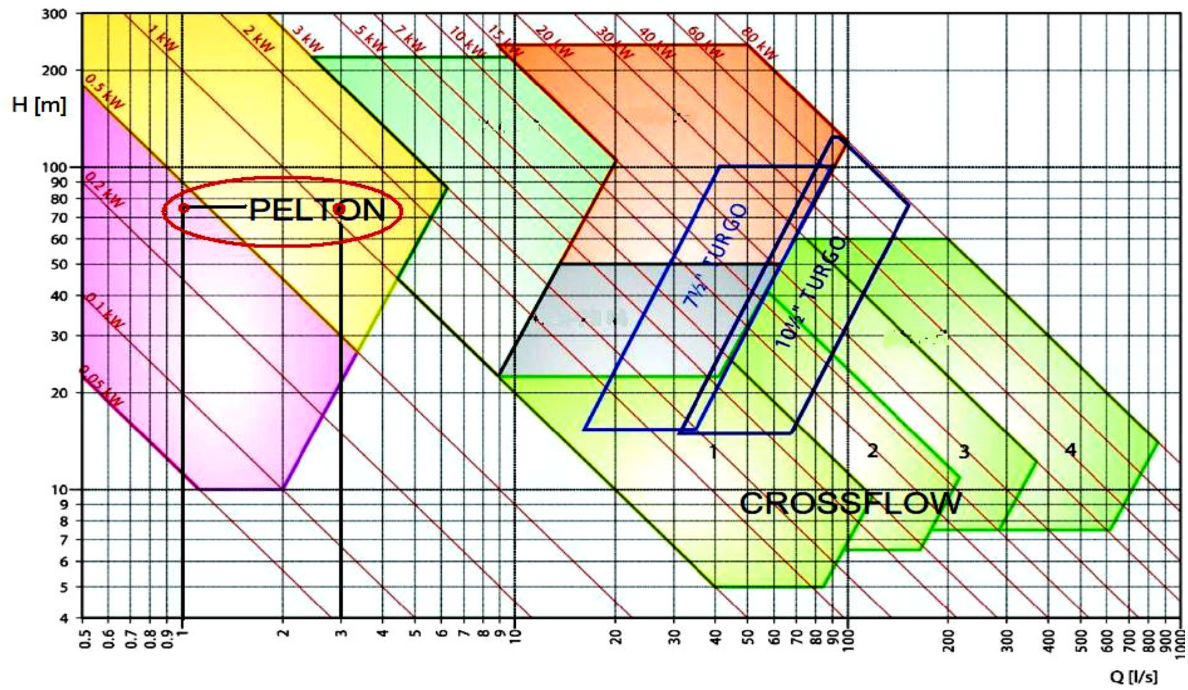
Potential power of the water source is shown for the two limit flows values (2). Minimum flow 1,0 (L/s), where the turbine is generating electricity, and maximum flow 3,0 (L/s).

$$P_{\min} = Q_{V1} \cdot H \cdot g \cdot \rho \cdot (1-\eta_{los}) = 0{,}001 \cdot 76 \cdot 9{,}81 \cdot 1000 \cdot (1-0{,}01) = 738(\mathrm{W}) \tag{2a}$$

$$P_{\max} = Q_{V3} \cdot H \cdot g \cdot \rho \cdot (1-\eta_{los}) = 0{,}003 \cdot 76 \cdot 9{,}81 \cdot 1000 \cdot (1-0{,}01) = 2214(\mathrm{W}) \tag{2b}$$

C. CHOICE OF THE SUITABLE MICROTURBINE

In this issue I restricted myself to the condicions, provided by the water source (low flow, high height drop). I chose the appropriate type of turbine (micro-pelton turbine) from the diagram (Img. 4) [5].



Img. 4. Choice of the water turbine according to volume flow and water drop.

D. DIAMETER OF THE TURBINE DRIVER

I calculated the diameter of the turbine driver according to the size of second-hand generator (synchronous electro motor) and its rotation frequency (1480/min). I also considered that the maximum power, redirected from the turbine into the production of electricity, is at half the rotational speed of the turbine rotor in “empty running”. I got a rough estimate of the diameter of the driver and appropriately transformed it into available actual supply size (175 mm) (Img. 5) [5].

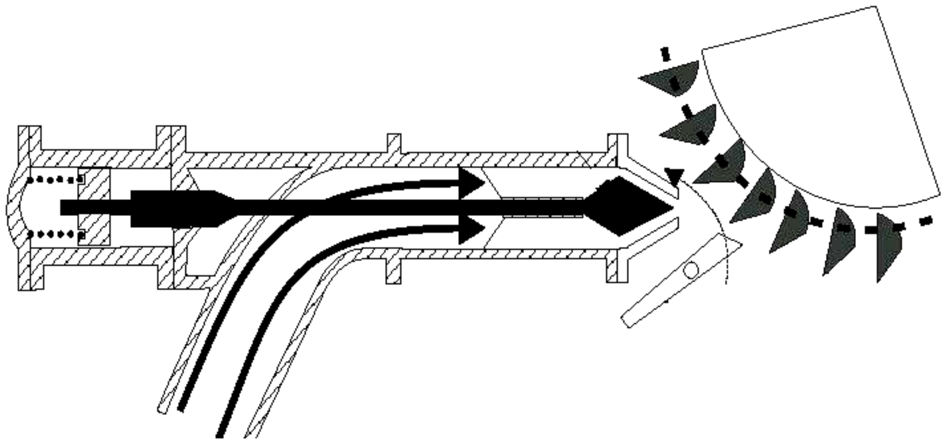
Img. 5. Rotor of the micro turbine with plastic spatulas (Image 6) and metal core.

Img. 6. Plastic spatulas.

E. DIMENSIONS OF THE INLET PIPE AND OF THE WATER NOZZLE

Based on the volume flow and available supply quantities of water to the turbine, I dimensioned the required diameter of the plastic pipe, that can withstand pressures up to 12 (Bar). I decided to choose "the alkaten pipe" (ϕ = 1,5'').

Due to the variable flow of the water source I chose a water nozzle (Img. 7)[2], which allows adjustment on the current situations of the water source.



Img. 7. Adjustable water nozzle.

[2] http://images.brighthub.com/A9/6/A96E8BCE31CD9B73454BCEBA3851452F3D0E603C_large.jpg

F. ELECTRICITY PRODUCTION

When converting mechanical rotational energy in produced electrical work it is necessary to take into account the efficiency of the turbine when rotating under the influence of the water jet and the efficiency of the generator while inducing electrical voltage and current in electrical network (Table 2).

Table 2. Efficiency of the turbine and of the generator when producing electricity.

Physical quantity	*Value*
Efficiency of the turbine, η_T	**0,92**
Efficiency of the generator (synchronous electro motor)	**0,80**

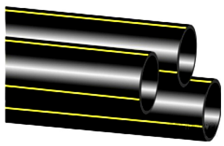
Actual powers, calculated according to the following parameters (flow, water drop, efficiency of the turbine and of the generator), represent the equations 4a and 4b.

$$P_{1L/s} = Q_{V1} \cdot H \cdot g \cdot \rho \cdot (1-\eta_{los}) \cdot \eta_T \cdot \eta_G = 738 \cdot 0,80 \cdot 0,92 = 543(W) \tag{4a}$$

$$P_{3L/s} = Q_{V3} \cdot H \cdot g \cdot \rho \cdot (1-\eta_{los}) \cdot \eta_T \cdot \eta_G = 2214 \cdot 0,80 \cdot 0,92 = 1630(W) \tag{4b}$$

3.2 Photos of the own realization of micro-hydro turbine

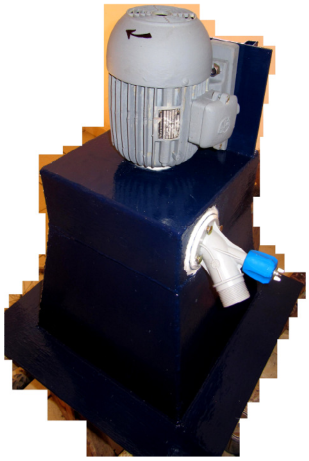
Img. 8. Water coverage from a water source.



Img. 9. Water pipe.

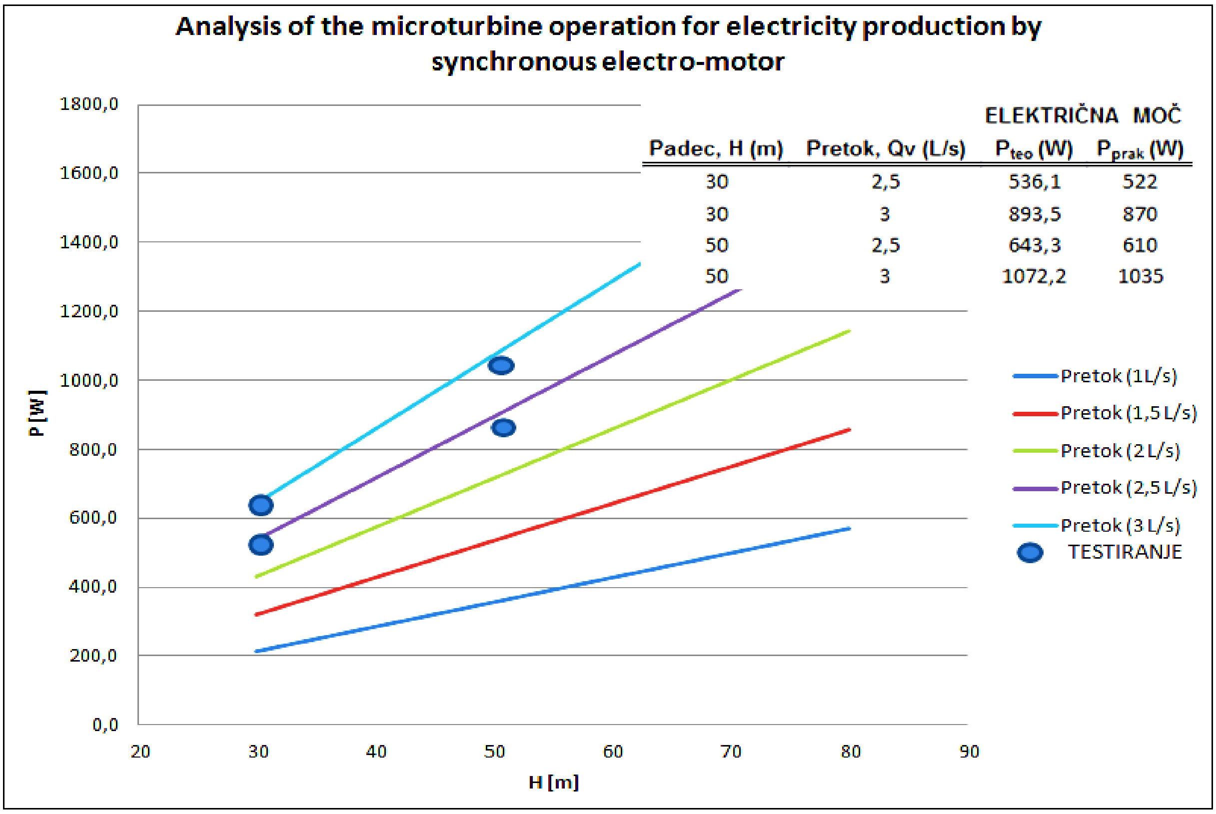
Img. 10. Rotor and water nozzle of microturbine.

Img. 11. Generator (synchronous electro motor).



Img. 12. Micro-pelton turbine with integrated generator, rotor and water nozzle.

3.3 Verification of the power plant operation



Img. 13. Theoretical power calculation at a given volume flow and water drop, and practically measured electrical power.

4. CONCLUSIONS

Slovenia has according to its geographical location underexploited water potential for electricity generation purposes. In the field of self-sufficiency a major barrier for small producers represents the disobedience of the country. This is reflected by the low purchase price of electricity and the bureaucratic difficulty of obtaining permits to build new power plants.

From the perspective of the environment and the increasing electricity demand much work needs to be done in the future, so that serious economic and homeland problems will be solved with small interventions in space.

5. SOURCES AND LITERATURE

[1] M. Tuma, "*Energetski stroji in naprave – Teoretične osnove*," Ljubljana: Fakulteta za strojništvo, 1989.
[2] S. Medved, P. Novak, "*Varstvo okolja in obnovljivi viri energije*," Ljubljana: Fakulteta za strojništvo, 2000.
[3] http://turbolab.fs.uni-mb.si/3_Pedago/gradivo/pdf/EPOS%2007-08%20CB.pdf .
[4] http://www.ecoinnovation.co.nz/p-19-pelton-turbine.aspx .
[5] http://www.microhydropower.net/basics/turbines.php#Pelton .

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